

Java™ magazine

By and for the Java community 

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submit an article proposal? Here's how.

A man with short grey hair and glasses, wearing a light blue button-down shirt and blue jeans with a brown belt, is walking towards the camera on a city sidewalk. He is holding a grey folder or tablet under his left arm. The background is a blurred city street with other pedestrians and buildings.

Delays in the delivery of major releases such as JDK 9 are common when community is valued.

For some in the Java community, this postponement and the fact that it came after several

However, what lets me abide the delay without complaint is that it derives from collaboration with the community. As anyone who has served on industry committees can tell you, collaborative work is difficult, noisy, and supremely frustrating. There is nothing quite like it, except perhaps parenting. Yet despite the frustrations, there is a conviction held by all parties that it is better to

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work through the hard parts of the collaboration than to abandon the effort. We are all better served by the collaboration than by insisting on our own preferences.

The understanding of collective benefit has long driven Java's history and is indisputably integral to its success. It can be easy to forget that the development of Java and the JVM is itself a collaborative effort. The development work is done as open source in public repositories, and the discussions about feature selection, code implementations, release dates, and other points of contention are held in public mailing lists. In fact, the recent decision regarding the new release date and the specific reasons for the delay were all posted and replied to on public forums.

Now, let me ask you, do you know of any other language whose principal corporate sponsor assigns more than 100 engineers to work on the language and yet defers on matters of release date to a community of partners? There are only three companies outside of Oracle that have made so large a commitment to language development: Apple, Google, and Microsoft. But none of them have adopted this open, consensual approach. (I'm not here deprecating those companies' work on their lan-

guages or their preferred approach, but rather I'm trying to underscore how unique Oracle's approach with Java is.)

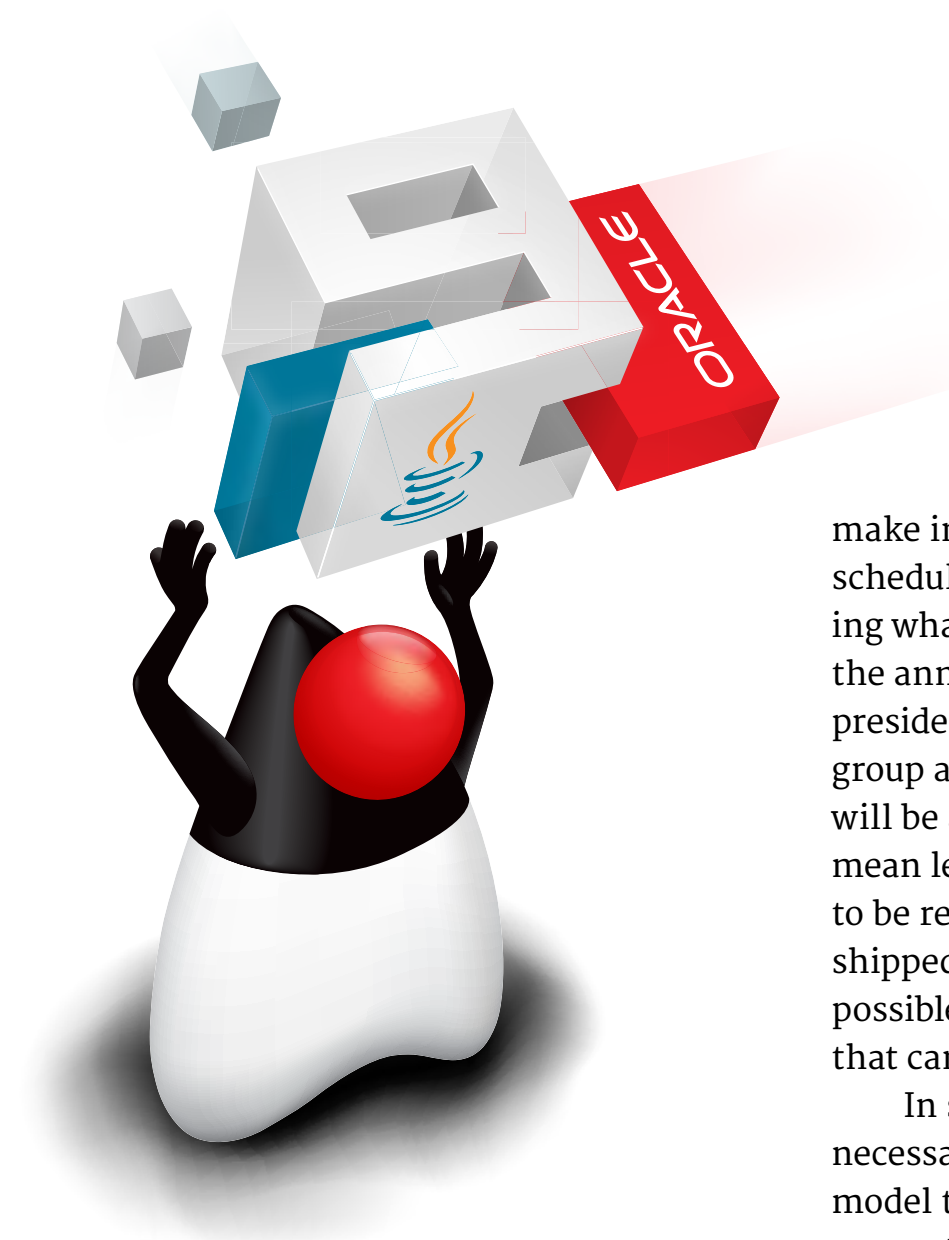
I recognize that my acceptance of delay in the name of collaboration is borne of an insider's view of Java community operations. Many Java developers have no interest in the politics behind release dates and couldn't care less whether discussions are held in public or not; they just want the new technology to be released and so are frustrated by the succession of delays.

This perspective is driving an initiative to

make innovations available on a predictable schedule. This new approach proposes publishing whatever technology is good to go when the announced date arrives. Georges Saab, vice president of development for the Java Platform group at Oracle, [states](#) that this new approach will be adopted in post-Java 9 releases. It will mean less waiting for a single central feature to be ready before lesser improvements are shipped. Ironically enough, this strategy is possible now *because* of the modularity in Java 9 that can localize the effects of a given change.

In sum, the delays of this release are the necessary product of the open, collaborative model that underlies Java's success. If you're a supporter of open source and open collaboration, then you surely recognize that such delays are a sacrifice that the process demands. In that sense, it is the antithesis of releasing by unilateral fiat. Nonetheless, I am excited that modularity makes possible future releases on a defined schedule while maintaining the commitment to high levels of collaboration.

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MAY/JUNE 2017

Exception Swallowing in Project Lombok

In your excellent May/June 2017 issue, I want to comment on your article “Project Lombok: Clean, Concise Code,” in which Josh Juneau presents a concise guide to using Lombok. On page 14, Juneau states, “The `@SneakyThrows` annotation can be placed on a method to essentially ‘swallow’ the exceptions.” I think this sentence is somewhat misleading. To me the term *swallow* means to catch the exception, do nothing with it, and continue execution of the code.

However, this is far from what Lombok is doing. From the Lombok site, “Lombok will not ignore, wrap, replace, or otherwise modify the thrown checked exception; it simply fakes out the compiler.” This means we will still get an exception bubbling through should one occur, but we don’t need to explicitly handle it in calling code, much like runtime exceptions.

—Syed Asghar

Author Josh Juneau responds: “Thanks for sending me this useful feedback. I am glad that you found the article useful. I can certainly see why you find the term swallow misleading with respect to the way in which the @SneakyThrows annotation handles checked exceptions. I do agree, after reassessing, that this was not an ideal choice of words. The Lombok @SneakyThrows annotation allows you to omit a try-catch clause and throw a checked exception—it does not silently swallow it. Perhaps the term hides would be more precise, as Lombok hides the requirement to code a try-catch clause by allowing you to throw a checked exception without it. As stated in the Lombok Javadoc, @SneakyThrows does not silently swal-

low, wrap into `RuntimeException`, or otherwise modify any exceptions of the listed checked exception types. The JVM does not check for the consistency of the checked exception system; `javac` does, and this annotation lets you opt out of its mechanism.”

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We welcome comments, suggestions, grumbles, kudos, article proposals, and chocolate chip cookies. All but the last two might be edited for publication. If your note is private, indicate this in your message. Write to us at javamag_us@oracle.com. For other ways to reach us, see the last page of this issue.



The JVM Language Summit is an open technical collaboration among language designers, compiler writers, tool builders, runtime engineers, and architects who target the JVM. The schedule consists of a single track of traditional presentations (about six each day) interspersed with workshop discussion groups. Each registrant is invited to suggest a few topics of interest for the workshops.

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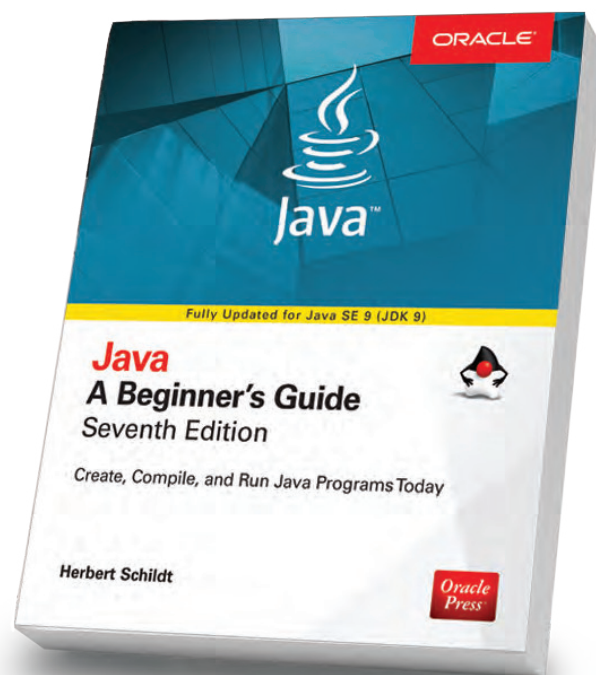
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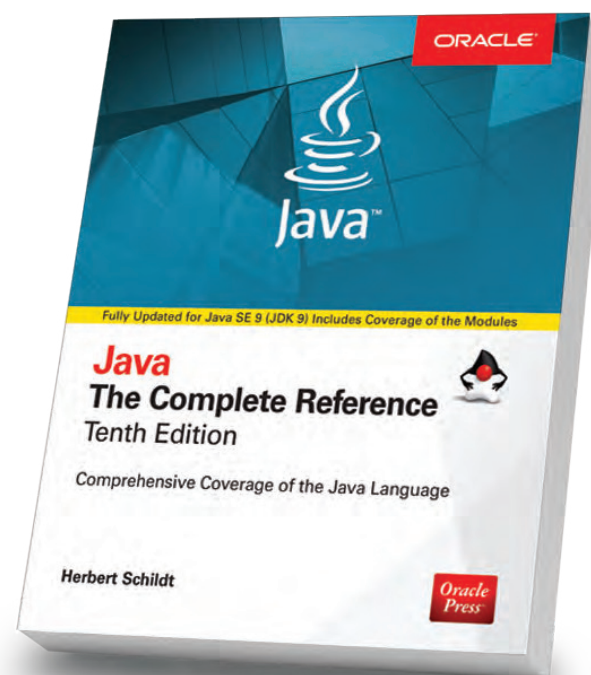
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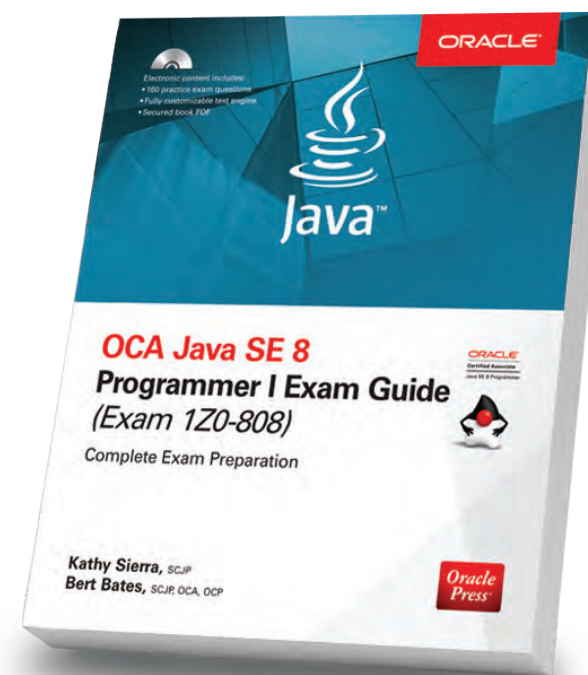
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SIMON RITTER

Nine New Developer Features in JDK 9

There's a lot more to this release than modules.

The big new feature in JDK 9 is the Java Platform Module System coupled with the introduction of the modular JDK. However, there are plenty of other new features in JDK 9, and in this article, I focus on nine that are of particular interest to developers. Where applicable, I've included the relevant JDK Enhancement Proposal (JEP) number so you can find more information.

Factory Methods for Collections (JEP 269)

Collections provide a well understood way for you to gather together groups (I was going to say *sets*, but that could be a bit misleading) of data items in your applications and then manipulate the data in a variety of useful ways.

At the top level, there are interfaces that represent the abstract concepts of a List, Set, and Map.

The problem, until now, has been that Java doesn't provide a simple way to create a collection with predefined data. If you want a collection to be structurally immutable (that is, you can't add, delete, or change references to elements), you need to do more work.

Let's look at a simple example using JDK 8:

```
List<Point> myList = new ArrayList<>();
myList.add(new Point(1, 1));
myList.add(new Point(2, 2));
myList.add(new Point(3, 3));
```

```
myList.add(new Point(4, 4));  
myList = Collections.unmodifiableList(myList);
```

It's not terrible, admittedly, but to create an immutable list of four `Points` required six lines of code. JDK 9 addresses this through factory methods for collections.

This feature makes use of a change introduced in JDK 8 that enabled static methods to be included in interfaces. That change means that you can add the necessary methods at the top-level interfaces (`Set`, `List`, and `Map`) rather than having to add them to a large group of classes that implement those interfaces.

Let's rewrite our example using JDK 9:

```
List<Point> list =  
    List.of(new Point(1, 1), new Point(2, 2),  
            new Point(3, 3), new Point(4, 4));
```

The code is now much simpler.

The rules that apply to the use of the different collections also apply (as you would expect) when using these factory methods. So, you cannot pass duplicate arguments when you create a `Set`, nor can you pass duplicate keys when you create a `Map`. A null value cannot be used as a value for any collection factory method. The Javadoc documentation provides full descriptions of how the methods may be called. [Collections

are discussed further in the article “Java 9 Core Library Updates: Collections and Streams” ([page 21](#)). —*Ed.*]

Optional Class Enhancements

The `Optional` class was introduced in JDK 8 to reduce the number of places where a `NullPointerException` could be generated by code (and it was frequently used to make the Stream API more robust).

JDK 9 adds three new methods to `Optional`:

- `ifPresentOrElse(Consumer action, Runnable emptyAction)`: Similar to `ifPresent`, but if there is no value, it executes the `emptyAction`.
- `or(Supplier supplier)`: This method is useful when you want to ensure that you always have an `Optional`. The `or()` method returns the same `Optional` if a value is present; otherwise, it returns a new `Optional` created by the supplier.
- `stream()`: Returns a stream of zero or one elements, depending on whether there is a value.

Stream API Enhancements

It's always useful to be able to create a stream source from a collection of data, and JDK 8 provided several methods to do this outside the Collections API (`BufferedReader.lines()`, for example). Several new sources are being added in JDK 9, such as `java.util.Scanner` and `java.util.regex.Matcher`.

JDK 9 adds four methods to the `Stream` interface.

First, there are two related methods: `takeWhile(Predicate)` and `dropWhile(Predicate)`. These methods are complementary to the existing `limit()` and `skip()` methods, but they use a `Predicate` rather than a fixed integer value. The `takeWhile()` method continues to take elements from the input stream and pass them to the output stream until the `test()` method of the `Predicate` returns true. The `dropWhile()` method does the opposite; it *drops* elements from

the input stream while the `test()` method of the `Predicate` returns true. All remaining elements of the input stream are then passed to the output stream.

Be careful when using either of these methods when you have an unordered stream. Because the predicate needs to be satisfied only once to change the state of elements being passed to the output, you might get elements in the stream that you don't expect, or you might miss some elements that you would get.

The third new method is `ofNullable(T t)`, which returns a stream of zero or one elements, depending on whether the value passed is null. This can be very useful to eliminate a null check before constructing a stream, and it is similar in a sense to the new `stream()` method in the `Optional` class discussed in the previous section.

The last new stream method is a new version of the static `iterate()` method. The version in JDK 8 took one parameter as the seed and created an infinite stream as output. JDK 9 adds an overloaded method that takes three parameters, which effectively gives you the ability to replicate the standard for loop syntax as a stream. For example, `Stream.iterate(0, i -> i < 5, i -> i + 1)` gives you a stream of integers from 0 to 4.

Read-Eval-Print Loop: jshell (JEP 222)

JDK 9 includes a new read-eval-print loop (REPL) command-line tool, `jshell`, that allows you to develop and test Java code interactively, unlike when you use an IDE, where code must be edited, compiled, and then run. Developers can quickly

JDK 9 includes a new read-eval-print loop (REPL) command-line tool, jshell, that allows you to develop and test Java code interactively.

prototype sections of code as `jshell` continually reads user input, evaluates it, and prints either the value of the input or a description of the state change the input caused.

To make the tool easier to use, it includes features such as an editable history, tab completion, automatic addition of terminal semicolons when needed, and configurable predefined imports and definitions. It is also possible to declare variables whose type is defined after the declaration (but this is still *not* dynamic typing: once the type is set, it can't be changed).

There is even a module, `jdk.jshell`, that can be used if you want to build your own “snippet” evaluation tool.

One of the most significant reasons for including a REPL in the JDK is to make it easier to use Java as a teaching language, lowering the amount of boilerplate code new developers need to write before they get results.

Concurrency Updates (JEP 266)

Java 5 introduced concurrency utilities to simplify writing Java code that has multiple cooperating threads. Subsequent releases have improved these features by adding things such as the fork/join framework in JDK 7 and, most recently, parallel streams in JDK 8. Now, JDK 9 provides enhancements for concurrency in two areas.

The first is a reactive streams publish-subscribe framework. Processing streams of elements in an asynchronous fashion can lead to problems when the rate at which elements are submitted to the processing code rises sharply. If the processor is unable to handle the load, the element supplier can be blocked or a buffer overflow situation can occur.

The introduction of private methods in interfaces will allow common code to be extracted to methods that will remain encapsulated within the interface.

Reactive streams use a publish-subscribe model in which the stream processor (the subscriber) subscribes to the supplier of elements (the publisher). By doing this, the supplier knows how many elements it can pass to the processor at any time. If the supplier needs to send more than this number, it can use techniques such as local buffering or it can use an alternative processor (this is a typical microservice approach that delivers horizontal scalability by spinning up new service instances to handle increased load).

JDK 9 includes a new class, `Flow`, that encloses several interfaces: `Flow.Processor`, `Flow.Subscriber`, `Flow.Publisher`, and `Flow.Subscription`. A `Subscription` is used to link a `Publisher` with a `Subscriber`.

The Subscription interface contains two methods:

- `cancel()`: This method causes the Subscriber to stop receiving messages (eventually).
- `request(long n)`: Add n elements to the number that the Subscriber is able to process. This method can be called repeatedly as the Subscriber processes elements and is ready to process more.

By implementing the `Processor` interface, a class can act as both a publisher and a subscriber, thereby acting as an intermediate operation in the stream.

The second new concurrency feature in JDK 9 consists of enhancements to the `CompletableFuture` class, which was introduced in JDK 8. Several new methods relate to adding time-based functionality. These enhancements enable the use of time-outs via methods such as `completeOnTimeout()`, `delayedExecutor()`, and `orTimeout()`. Other new methods include `failedFuture()` and `newIncompleteFuture()`.

Milling Project Coin (JEP 213)

One of the most significant changes in JDK 7 was Project Coin, which was a set of small language changes to smooth out some of the common tasks developers undertake repeatedly in Java. The project included things such as the ability to

use Strings as constants in switch statements. JDK 9 builds on this and adds a few more small changes to the language syntax of Java:

- Effectively final variables can be used in try-with-resources without being reassigned. Currently, each resource that is used must be assigned to a new variable, even if that resource has already been defined in the method. With this change, it is now possible to use an existing variable (as long as it is effectively final) without reassigning it. Here is an example of the change:

```
try (Resource r = alreadyDefinedResource) ...
```

In JDK 9, it becomes this:

```
try (alreadyDefinedResource) ...
```

- Private methods can be used in interfaces. Interfaces changed in a big way in JDK 8. First, there was the introduction of default methods, which allowed new methods to be added to existing interfaces without forcing a break in backward compatibility. Because this meant that behavior could be included in an interface (giving Java multiple-inheritance of behavior for the first time), it was also logical to include static methods. In JDK 9, the introduction of private methods in interfaces will allow common code to be extracted to methods that will remain encapsulated within the interface.
- The diamond operator can be used with anonymous classes. One of the things included in JDK 8 and now JDK 9 is better type inference. Being able to use lambda expressions without explicitly specifying the types of parameters is a good example of this. This ability required a substantial rewrite of how the Java compiler processes type inference, and the diamond operator change in JDK 9 makes use of that compiler change. The problem, as it existed before, was that using the diamond operator with an anonymous class could

result in a type being inferred that is not denotable. A type that is not denotable can be represented by the compiler, but it cannot be expressed to the JVM using the class signature attribute. In JDK 9, it is now possible to use the diamond operator with an anonymous class as long as the inferred type *is* denotable, for example:

```
List<String> myList = new ArrayList<>() {
    // Overridden methods
};
```

- A single underscore will no longer be valid as an identifier. I often ask, during Java 9 presentations, if anyone has ever used a single underscore as a variable name and, thankfully, few people have. The reason for doing this is that in a later release of the JDK (presumably JDK 10), it will be valid to use a single underscore as a variable name *only* in lambda expressions. This makes sense. You could use a single underscore if your lambda expression takes only one argument and you don't use the argument in the body of the lambda, for example:

```

-> getX()

```

(For those of you who like the idea of underscores as variable names, you can still use two or more as an identifier.)

- Extended use of the `@SafeVarargs` annotation is allowed. Currently, this annotation can be used only on constructors, static methods, and final methods, none of which can be overridden. Because a private method cannot be overridden by a subclass, it is logical also to enable private methods to use this annotation.

The ProcessHandle interface identifies and provides control of native processes.

Spin-Wait Hints (JEP 285)

This is a small change because it adds only a single method, but its addition to the Thread class is significant. The other interesting aspect of this feature is that it is the first JEP to be included that was proposed by a company other than Oracle (in this case, Azul Systems).

The `onSpinWait()` method provides a hint to the JVM that the thread is currently in a processor spin loop. If the JVM and hardware platform support optimizations when spinning, such hints can be used; otherwise, the call is ignored. Typical optimizations include reducing thread-to-thread latencies and reducing power consumption.

Variable Handles (JEP 193)

One of the most significant changes in JDK 9 caused by modularizing the core JDK libraries is the encapsulation of the internal APIs by default. Probably the most well known of these is `sun.misc.Unsafe`. To make some of the functionality of this private API available through a public API, JDK 9 introduces the `VarHandle` class.

Variables are used in Java all the time. They are implicit pointers to areas of memory that hold values. A variable handle is a typed reference to a variable (so for those who've used C and C++, it's effectively a pointer to a pointer).

In order to get a reference to a `VarHandle`, you use the `MethodHandle.Lookup` class that has been extended in JDK 9. You can retrieve references to either static or nonstatic variables, as required, as well as to arrays.

Once you have a `VarHandle`, you can execute low-level memory ordering operations on the variable it references. This capability allows you to perform atomic operations, such as

With features such as these, you should **consider migrating your development to this release ASAP.**

compare-and-set operations, but without the performance overhead that is associated with using the equivalent classes and methods of the `java.util.concurrent.atomic` package.

You can also use a `VarHandle` to “fence” operations, giving you fine-grained control over the memory ordering of operations such as read and write or store and load. This can be useful in situations where you don’t want the Java compiler or JVM to reorder operations, which is often done to optimize the performance of code paths.

Process API Updates (JEP 102)

JDK 9 contains enhancements to the `Process` and `ProcessBuilder` classes and introduces a new `ProcessHandle` interface. `ProcessBuilder` now includes the method `startAsPipeline()`. As the name suggests, this method constructs a UNIX-style pipeline of processes using a list of `ProcessBuilders`. As each process is started, its standard output is connected to the standard input of the next process.

Here's a simple example that pipes the output of the UNIX/Linux `ls` command on `/tmp` through `wc -l` to get a count of the number of files in the `tmp` directory:

```
ProcessBuilder ls = new ProcessBuilder()
    .command("ls")
    .directory(Paths.get("/tmp").toFile());
ProcessBuilder wc = new ProcessBuilder()
    .command("wc", "-l")
    .redirectOutput(Redirect.INHERIT);
List<Process> lsPipeWc = ProcessBuilder
    .startPipeline(asList(ls, wc));
```

The `ProcessHandle` interface identifies and provides control of native processes. It provides methods to retrieve information about a process, such as the process ID as well as any child and descendant processes. Also, there is a static method that returns an `Optional<ProcessHandle>` for a given process ID.

Simon Ritter (@speakjava) is the deputy CTO of Azul Systems. He has been in the IT business since 1984 and holds a BS in physics from Brunel University in the UK. He joined Sun Microsystems in 1996 and spent time working in both Java development and consultancy. Ritter has been presenting Java technologies to developers since 1999, focusing on the core Java platform as well as client and embedded applications.

One way or the other, you should be able to find good substitutes for jhat.



TRISHA GEE

Migrating from Java 8 to Java 9

Step-by-step work can lead to the adoption of all or some of the features even without using modules.

This article shows the steps you take to run Java 8 code and use some of the new features of Java 9 without migrating to modules. I principally examine what you need to do to get the code compiling and running.

Getting Started

First, download and install the latest version of JDK 9. At the time of this writing, it is still an Early Access release and can be found [here](#) (in this article, I'm using build 9-ea+166).

Until the impact of Java 9 on your system is understood, you probably don't want it to be the default Java version. So, instead of updating \$JAVA_HOME to point to the new installation, you might want to create a new environment variable, \$JAVA9_HOME, instead. I'll be using this approach throughout this article.

You should also look at this detailed [migration guide](#) to get a feel for what steps might be needed.

Before Jumping In

You can determine the amount of effort that might be required to migrate to Java 9 without even downloading or using it. There are several tools available in Java 8 that will give you appropriate hints.

Compiler warnings. First, of course, you can look at any compiler warnings, because some of those will tell you about potential problems (see [Figure 1](#)).

I'm using my IDE, IntelliJ IDEA, to compile the code and to show me the warnings, but what you see in the messages box in [Figure 1](#) is the same as what you'd see using javac from the command line. Other IDEs, such as NetBeans and Eclipse, will have similar functionality. In [Figure 1](#), you can see that the code has a field with a single underscore as a name. This single-underscore name has been [removed as a legal identi-](#)

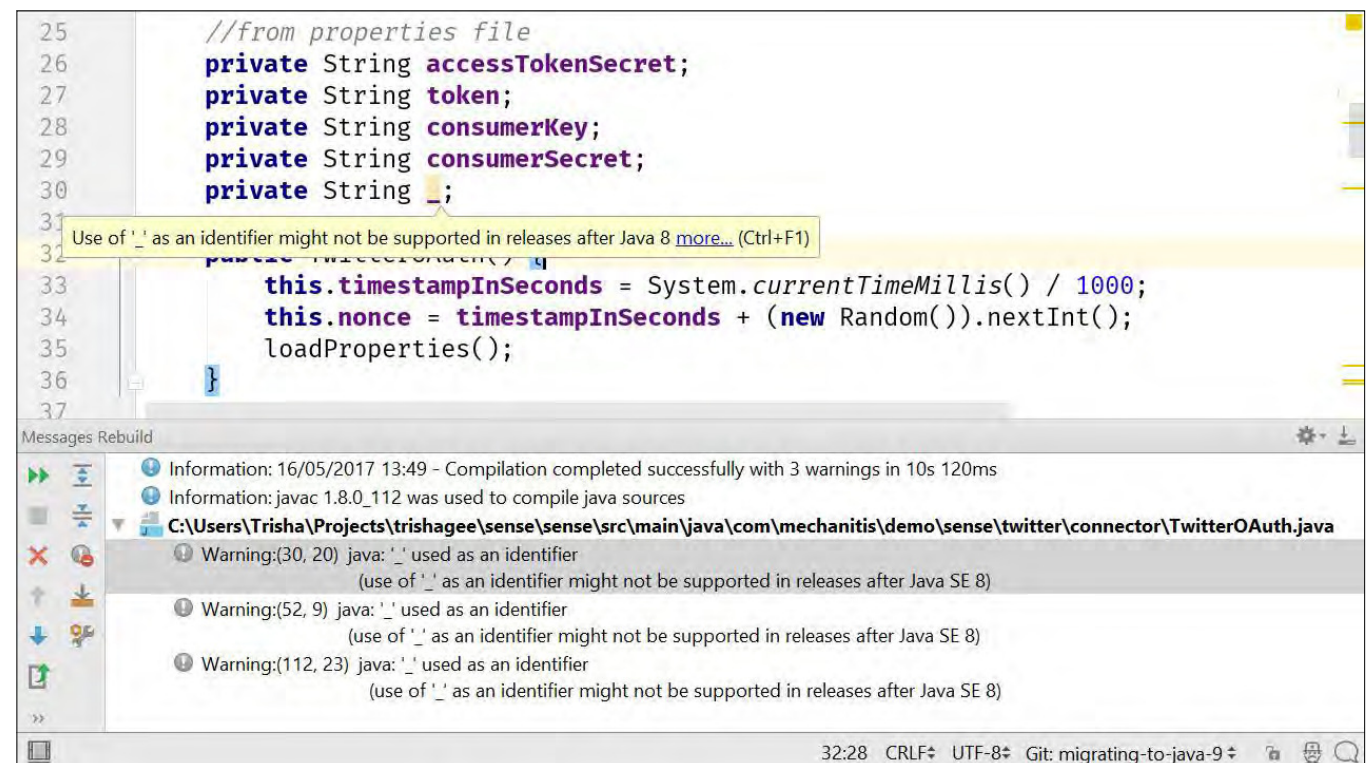


Figure 1. Example compiler warning about a potential problem

I navigate to the location of my class files via the command line (**Figure 2** shows that this is `%PROJECT%\%MODULE%\build\classes`) and from there, I run `jdeps` with the `-jdkinternals` flag. I'm using Windows, so my command line is the following, where `main` is the name of the directory containing my classes:

When I run this command, I get the output in Figure 3.

These messages indicate that my `TwitterOAuth` class is using the internal classes `sun.misc.BASE64Encoder` and `sun.misc.Unsafe`. The output suggests a replacement for the encoder, `java.util.Base64`, which was a new class in Java 8. `unsafe` is a special case, because there is no suitable replacement for all of its functionality yet.

JEP 260 talks about which internal APIs are going away and which will remain accessible. Java team member Mark Reinhold provided the following summary in an email to one of the principal JDK mailing lists to explain how each API will be handled by the Java team:

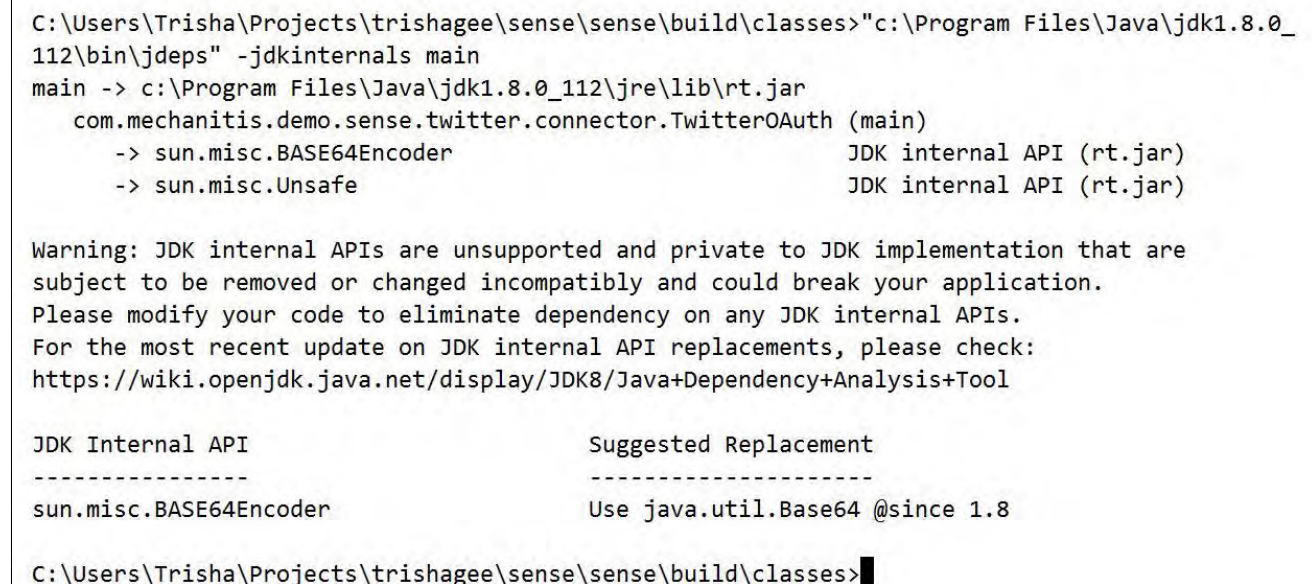


Figure 3. Output from running jdeps

- If it has a supported replacement in JDK 8, then we will encapsulate it in JDK 9.
- If it does not have a supported replacement in JDK 8, then we will not encapsulate it in JDK 9, so that it remains accessible to outside code.
- If it has a supported replacement in JDK 9, then we will deprecate it in JDK 9 and encapsulate it, or possibly even remove it, in JDK 10.

Compiler warnings and `jdeps` can show you areas in your code that might be problematic in Java 9 and even suggest solutions. These problems can be fixed while you're still running with an earlier version of Java (provided the suggested replacement classes are available in that version), and doing so will ease your transition to Java 9.

Running with Java 9

The migration guide I mentioned earlier suggests running your application with Java 9 before recompiling or making any other changes. One place you might want to do this testing is in a continuous integration (CI) environment: you can use the artifacts built with your current version of Java but run the application and its tests with Java 9.

However, at the time of this writing, many of the common CI servers and some build tools, such as Gradle, do not yet fully support Java 9. If your project uses Maven, a few CI servers, such as TeamCity, will be able to compile or run your code with Java 9. But because the JDK and JRE were restructured as part of Java 9, some tools will need to be updated to work correctly.

You should find out which CI server and build tool your team

Java 9 contains several changes that might affect your application; some might not cause compilation errors but instead will demonstrate different behavior.

uses, and determine whether they and the related parts of the toolchain presently support running with Java 9.

Compiling with Java 9

If you followed my previous advice, compiling with Java 9 should be simple. In my code, if I compile with Java 9 without fixing those errors identified in **Figure 1** and **Figure 3**, I will get the two errors I was expecting: one error stating I cannot use underscore as a field name and one that shows I can no longer access `BASE64Encoder`. Both of these are straightforward to fix. For the first, I rename the field. For the second, I import `java.util.Base64` and replace the following old line of code:

```
String encodedString =
    new BASE64Encoder().encode(bytes);
```

with this:

```
String encodedString =
    Base64.getEncoder().encodeToString(bytes);
```

The use of `sun.misc.Unsafe` won't give me an error or warning (at this point), because it's still accessible in Java 9. See [“Removed or Changed APIs”](#) for more examples of changes that might affect your code.

The external libraries my application depends on all work with Java 9, so after I apply the two fixes above, everything compiles and runs as expected. However, you might find that some of the libraries you're using aren't compatible with Java 9. There is a [list of major open source libraries](#) that have been testing with Java 9. If you have a problem with a library, you should check whether there is an updated version of the library that supports Java 9.

Unexpected Behavior

Java 9 contains several changes that might affect your appli-

- [JEP 231: Remove Launch-Time JRE Version Selection](#)
- [JEP 240: Remove the JVM TI hprof Agent](#)
- [JEP 241: Remove the jhat Tool](#)
- [JEP 260: Encapsulate Most Internal APIs](#)
- [JEP 289: Deprecate the Applet API](#)
- [JEP 298: Remove Demos and Samples](#)
- [JEP 214: Remove GC Combinations Deprecated in JDK 8](#)
- [JEP 248: Make G1 the Default Garbage Collector](#)
- [JEP 271: Unified GC Logging](#)
- [JEP 158: Unified JVM Logging](#)
- [JEP 223: New Version-String Scheme](#)
- [JEP 245: Validate JVM Command-Line Flag Arguments](#)

In this article, I have examined how to port Java 8 code to Java 9, without getting into the question of modularity. This explanation is intended for readers who want to use many of the innovations in Java 9 discussed here and in the accompanying article by Simon Ritter, “Nine New Developer Features in JDK 9.” [As this issue goes to press, modules have not been finalized by the Java Community Process, so coverage of working with modules will appear in a forthcoming issue of *Java Magazine*. —Ed.] `</article>`

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RAOUL-GABRIEL **URMA**
AND
RICHARD **WARBURTON**

Java 9 Core Library Updates: Collections and Streams

Collections, Streams, and iterators have all added new capabilities.

Java 9 introduces many refinements to Java 8 features, such as Streams, Collectors, Optional, and CompletableFuture, as well as enhancements to the Collections API. This article focuses on using the new features in Collections, Streams, and Collectors. In the next issue, we will focus on reliability using Optional and CompletableFuture.

Collection Factories

Java 9 adds a set of new factory methods to the Collections Framework. Let's start by looking at the problem these methods are trying to solve, by instantiating a list with a few String values:

```
List<String> values = new ArrayList<>();
values.add("Java 9");
values.add("is");
values.add("here");
```

Let's face it: this is bulky for such a simple and common thing to do. We admit that this isn't the only way to instantiate a List though. `Arrays.asList()` has been around since before Java 5, and it originally took just an array. In Java 5, it was converted to accept varargs and is in common use.

```
List<String> values =  
    Arrays.asList("Java 9", "is", "here");
```

This is a helpful improvement. The List returned by `Arrays.asList()` is a little strange, however. If you try to add an element to the List, it'll throw an `UnsupportedOperationException`. You might think that is OK—after all, it's a List that cannot be mutated. Not so fast: it's actually a list that wraps an array. So the `set()` operation will modify the backing array and, in fact, if you hold onto the array that is wrapped, it can be modified. If you want to create a Set or a Queue, you are out of luck as well; there's no `Arrays.asSet()`. The normal way to solve this problem is to use the Collection constructor overload:

```
Set<String> values =  
    new HashSet<>(Arrays.asList(  
        "Java 9", "is", "here"));
```

Again, this is fairly verbose. Note that some programming languages offer a feature to solve this problem by adding collection literals to the programming language. This gives you some syntax that instantiates a collection from specific values. Here's an example in Groovy:



```
def values = ["Hello", "World", "from", "Java"] as Set
```

One solution to implementing this is to provide some methods that construct collections from values and then use a varargs constructor to make them syntactically shorter, similar to collection literals. This is the approach used in Java 9, so you can do the following, which is a lot more concise:

```
List<String> list =  
    List.of("Java 9", "is", "here");  
Set<String> set =  
    Set.of("Hello", "World", "from", "Java");
```

Maps now also have similar factory methods. They work differently because Maps have keys and values rather than a single type of element. For up to 10 entries, Maps have overloaded constructors that take pairs of keys and values. For example, you could build a map of people and their ages, like this:

```
Map<String, Integer> nameToAge
    = Map.of("Richard", 49, "Raoul", 47);
```

The varargs case for Maps is a little bit harder: you need to have both keys and values, but in Java, methods cannot have two varargs parameters. Therefore, the general case is handled by taking a varargs method of `Map.Entry<K, V>` objects and adding a static `entry()` method that constructs them:

```
Map<String, Integer> nameToAge =  
    Map.ofEntries(entry("Richard", 49),  
                   entry("Raoul", 47));
```

The goal here isn't just to reduce verbosity; it is also to reduce the possibility of programmer errors. All the collections added in recent years have banned the use of nulls as elements within collections, and these collections follow suit. This helps

reduce the scope for bugs related to referring to null values in collections. It also simplifies the internal implementation.

A bigger difference, compared to most collections in the JDK, is that these collections are immutable. Immutability reduces the scope for bugs by removing the ability for one part of an application to cause problems by modifying state that another component is relying on. Immutability is a concept that has been advocated by functional programming for a long time. Speaking of functional programming, let's look at the updates to the Streams API in Java 9.

Streams

Streams were a great addition to Java 8. The code that developers write using streams tends to read a lot more like the problem they are trying to solve, and less code is usually required. Java 9 brings some small improvements to streams. **ofNullable**. The Stream interface has a pair of factory methods called `of()` that allow you to create streams from prespecified values: one is an overload for a single value, and the other takes a varargs parameter. These are very useful when you're trying to test streams code and when you want to just instantiate a stream with a few values. Java 9 adds an `ofNullable()` factory. Let's see how you might use this functionality.

Let's suppose you're trying to find a location where you can put some configuration files in a Java application. You want to use a couple of different properties: let's say `app.config` and `app.home`. Let's write this code in Java 8:

```
String configurationDirectory =  
    Stream.of("app.config", "app.home", "user.home")  
        .flatMap(key -> {  
            final String property =  
                System.getProperty(key);  
            if (property == null)  
            {  
                return Stream.empty();  
            }  
        })  
        .findFirst().get();
```


While `filter` retains all elements in the Stream that match its predicate, `takeWhile` stops once it has found an element that fails to match. The `dropWhile` operation does the inverse: it throws away the elements at the start for which the predicate is false.

So far, we've talked about streams that have a defined order: an *encounter order*. The order of a stream can be defined at its source. For example, if you're streaming from a list of values, the order in the list is the encounter order. It is also possible to have Stream operations that introduce an encounter order into their pipeline, for example, `sorted()`. Most, but not all, of the practical use cases of `takeWhile()` and `dropWhile()` rely upon their input streams having a defined encounter order.

One use case for applying `takeWhile()` on an unordered stream is if you want to be able to stop the Stream operation. For example, perhaps you have a Stream operation that may operate on an infinite stream, processing all the data in it, but you want to be able to stop the Stream when your application shuts down or a user needs to cancel the stream pipeline. You can do this with a `takeWhile()` operation that reads from a piece of external state, such as a volatile boolean flag. When you want to stop the stream pipeline, you simply set the state to false.

iterate. A related update is the introduction of an alternative `iterate()` method for creating streams. The vintage `iterate` method from Java 8 takes an initial value and a function that provides the next value in the stream. Look at the following example:

```
IntStream.iterate(3, x -> x + 3)
    .filter(x -> x < 100)
    .forEach(System.out::println);
```

This code prints all the numbers that are divisible by 3 and less than 100. It starts with 3, which is divisible by 3, and adds

3 on every iteration. It then filters to ensure that the numbers are less than 100 and uses a method reference to print the resulting numbers. It looks straightforward, but if you run it, you'll find that there's a big problem. Go on: try it!

That's right: the program never terminates. It keeps adding 3 in a loop infinitely. That's because there's no way to know in the filter that the numbers continue to increase. You can solve that problem with the new version of `iterate` in Java 9, which takes a predicate as its second argument that indicates at what point to stop iterating up. So, rewrite the code as follows:

```
IntStream.iterate(3, x -> x < 100, x -> x + 3)
    .forEach(System.out::println);
```

It now stops running after it has printed the number 99. The sample code here used the `IntStream` interface because it was operating on primitive `int` values, but the `iterate()` methods appear on both the primitive and regular `Stream` interfaces. Streams weren't added on their own in Java 8; they came with a powerful `Collectors` class that has also been improved in Java 9, as discussed next.

Collectors

Collectors were another important addition to Java 8. Collectors let you specify data processing queries by aggregating the elements of a Stream into various containers such as Map, List, and Set. For example, you can create a map of the sum of expenses for each year by using the `groupingBy` and `summingLong` collector from the Collectors class. In the rest of this article, assume that there are static imports when a static method is referred to from the Collectors class.

```
Map<Integer, Long> yearToSum
    = purchases.stream()
        .collect(groupingBy(Expense::getYear,
```


criteria in a given year and thus return an empty list.

```
Map<Integer, List<Expense>> yearToExpensiveExpenses =
    purchases.stream()
        .collect(
            groupingBy(
                Expense::getYear,
                filtering(expense ->
                    expense.getAmount() > 1_000,
                    toList())));
```

flatMap. The `flatMap` collector is the big brother of the mapping collector. Let's say you need to produce a map of years with a set of tags from the expenses for each year. In other words, you need to produce `Map<Integer, Set<Tag>>`.

A first attempt might look like this:

```
expenses.stream()
    .collect(
        groupingBy(
            Expense::getYear,
            mapping(Expense::getTags, toSet())));
```

Unfortunately, this query will return a `Map<Integer, Set<List<Tag>>>`.

By using `flatMap`, you can flatten the intermediate Lists into a single container. The `flatMap` collector takes two arguments: a function from one element to a Stream of elements and a downstream collector to collect the single flattened stream into a container. With this, you can solve the query, as follows:

```
Map<Integer, Set<String>> =
    expenses.stream()
        .collect(
            groupingBy(
```

```
Expense::getYear,  
flatMapping(expense ->  
    expense.getTags().stream(),  
    toSet())));
```

Note that the `flatMap` collector is related to the `flatMap` method from the Stream API. That method takes a function producing a Stream of zero or more elements for each element in the input Stream. The result is then flattened into a single Stream.

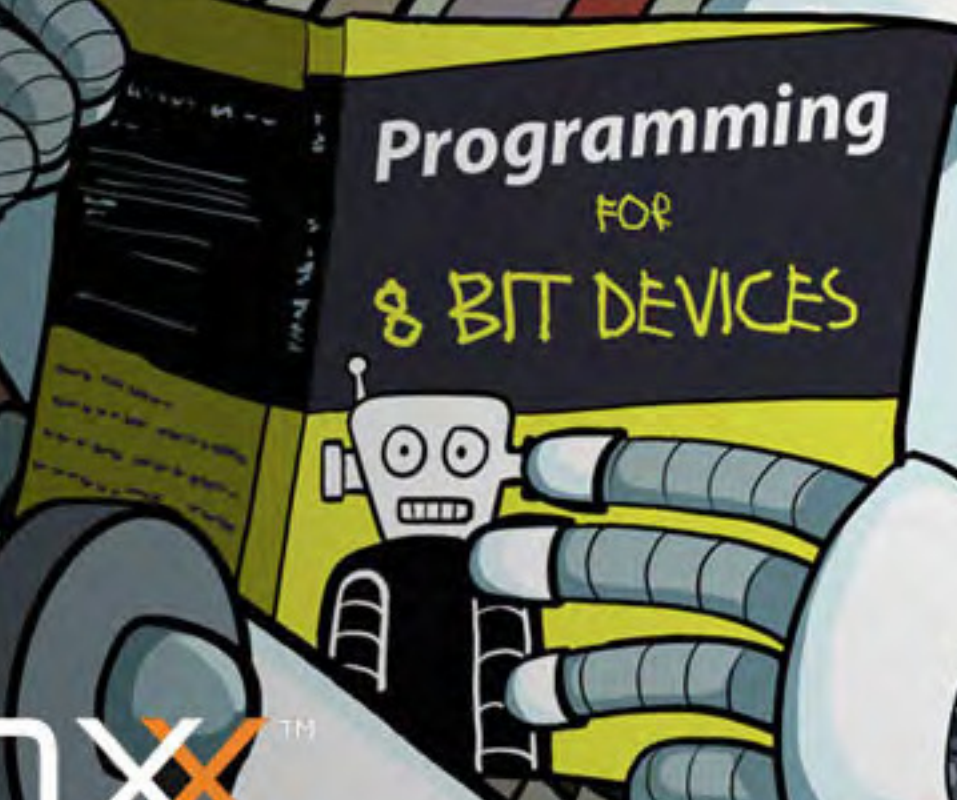
Conclusion

Java 9 adds new goodies to improve patterns by introducing new operations to Collections, Streams, and Collectors. These additions help you write code that reads closer to the problem statement and is easier to understand. Often when there are major new releases, developers focus only on the flagship features, but in practice, many developer productivity improvements can be found in the enhancement features of recent releases. Java 8 was a fantastic release, and Java 9 now makes some common patterns even simpler to use. </article>

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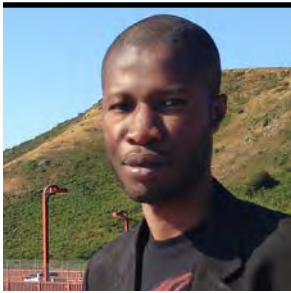
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CONSTANTIN DRABO

JShell: Read-Evaluate-Print Loop for the Java Platform

Testing code snippets is now part of the JDK.

JShell, a new read-evaluate-print loop (REPL), will be introduced in JDK 9. Motivated by project Kulla (JEP 222), JShell is intended to provide developers an API and an interactive tool that evaluates declarations, statements, and expressions of the Java programming language.

In this article, I present a brief overview of JShell, explain its use, and demonstrate its benefits for developers.

Overview

JShell is a new tool in JDK 9 that offers a basic shell for Java that uses a command-line interface. It is also the first official REPL implementation for the Java platform, even though this concept has existed in many languages (for example, Groovy and Lisp) and in Java third-party tools (such as Java REPL and BeanShell). So, it is not a new language, nor is it an IDE or a new compiler for Java.

JShell acts like a UNIX shell: it reads the instructions, evaluates them, prints the result of the instructions, and then displays a prompt while waiting for new commands. It is built around several core concepts—snippets, state, wrapping, instruction modification, forward references, and snippet dependencies—that I'll explain.

How to Run JShell

In order to run JShell, you need to download and install the

latest Early Access preview build for JDK 9 for your environment. Then, set your `JAVA_HOME` environment variable and run `java -version` to verify your installation. The output of the command should show something similar to the following:

```
java version "9-ea"
Java(TM) SE Runtime Environment (build 9-ea+173)
Java HotSpot(TM) 64-Bit Server VM...
```

To run JShell, type `jshell` at the command line:

```
[pandaconstantin@localhost ~]$ jshell
| Welcome to JShell -- Version 9-ea
| For an introduction type /help intro
```

When the prompt is available, you can get help on several useful commands by typing `/help` at the command line. **Figure 1** shows the partial output from that command, with many of the principal commands explained succinctly.

To understand how JShell works, let's look at a few code snippets. A *snippet* is an instruction that uses standard Java syntax. It represents a single expression, statement, or declaration. The following is a simple snippet. The text below the command is JShell output:


```
System.out.println("My JShell snippet");  
My JShell snippet
```

(In my examples in this article, the characters in blue indicate text entered at the command line into JShell, and the resulting output is shown in black monospace.)

Like Java code, JShell allows you to declare variables, methods, and classes:

```
int x, y, sum
```

```

/list [<name or id>|-all|-start]
    list the source you have typed
/edit <name or id>
    edit a source entry referenced by name or id
/drop <name or id>
    delete a source entry referenced by name or id
/save [-all|-history|-start] <file>
    Save snippet to a source file.
/open <file>
    open a file as source input
/vars [<name or id>|-all|-start]
    list the declared variables and their values
/methods [<name or id>|-all|-start]
    list the declared methods and their signatures
/types [<name or id>|-all|-start]
    list the declared types
/imports
    list the imported items
/exit
    exit the jshell
/history
    History of what you have typed
/!
    Re-run last snippet

```

Figure 1. Partial list of JShell commands

```
x ==> 0
y ==> 0
int sum ==> 0
```

```
x = 10 ; y = 20 ; sum = x + y;  
x ==> 10  
y ==> 20  
sum ==> 30
```

```
System.out.println("Sum of " + x + " and " + y +  
    " = " + sum);  
Sum of 10 and 20 = 30
```

Here's an example of a valid class, which I use later:

```
class Student {  
    private String name ;  
    private String classRoom ;  
    private double grade ;  
  
    public Student() {  
  
    }  
  
    public String getName() {  
        return name ;  
    }  
  
    public void setName(String name) {  
        this.name = name ;  
    }  
  
    public String getClassRoom() {  
        return classRoom ;  
    }  
}
```

```
public void setClassRoom(String classRoom) {
    this.classRoom = classRoom ;
}

public double getGrade() {
    return grade ;
}

public void setGrade(double grade) {
    this.grade = grade ;
}

}

created class Student
```

The indentation looks different than in Java, because this code was typed at the JShell command line. Some normal Java statements are not needed at this initial declaration. For example, JShell automatically imports many typical packages. In our example, the following imports were done automatically:

```
import java.io.*
import java.math.*
import java.net.*
import java.nio.file.*
import java.util.*
import java.util.concurrent.*
import java.util.function.*
import java.util.prefs.*
import java.util.regex.*
import java.util.stream.*
```

At any given point, you can see the already imported packages with the `/import -all` command listed earlier.

State. Each statement in JShell has a state. The state defines the execution status of snippets and of variables. It is deter-

mined by results of the `eval()` method of the JShell instance, which evaluates code. There are seven status states:

- **DROPPED:** The snippet is inactive.
- **NONEXISTENT:** The snippet is inactive because it does not yet exist.
- **OVERWRITTEN:** The snippet is inactive because it has been replaced by a new snippet.
- **RECOVERABLE_DEFINED:** The snippet is a declaration snippet with potentially recoverable unresolved references or other issues in its body.
- **RECOVERABLE_NOT_DEFINED:** The snippet is a declaration snippet with potentially recoverable unresolved references or other issues. (I discuss the difference between this and the previous state shortly.)
- **REJECTED:** The snippet is inactive because it failed compilation upon initial evaluation and it is not capable of becoming valid with further changes to the JShell state.
- **VALID:** The snippet is a valid snippet.

When a snippet is not declared, it is considered inactive and not part of the state of the JShell instance nor is it visible to the compilation of other snippets. At this stage, it is a `NONEXISTENT` snippet.

If the snippet is submitted to the `eval()` method and there are no errors, it becomes part of the state of the JShell instance and the status is `VALID`. Querying JShell gives `isDefined == true` and `isActive == true`.

In the case where the signature of the snippet is valid but the body contains issues or unresolved references, the status is `RECOVERABLE_DEFINED` and a JShell query states `isDefined == true` and `isActive == true`.

If the signature of the snippet is wrong and the body also contains issues or unresolved references, the snippet's status is `RECOVERABLE_NOT_DEFINED` and the status is `isDefined = false` even though the snippet stays active (`isActive == true`).

A snippet becomes REJECTED when compilation fails,

cannot modify classes at the top level; however, as seen in the following code, you can modify methods within classes.

```
class Person {  
  
    private String firstName ;  
    private String lastName ;  
  
    public String concatName(String firstName,  
        String lastName) {  
        return firstName + lastName;  
    }  
}  
| created class Person
```

Because each statement or expression is created in its own unique namespace, modifications can be applied at any time without disturbing the overall functioning of the code.

Forward References and Dependencies

Within the body of a class, you can refer to members that will be defined later. During evaluation of the code, the references produce errors. But because JShell works sequentially, the issue can be resolved by writing the missing member before actually calling the snippets.

When a snippet A depends on a second snippet B, any changes in snippet B are immediately propagated in A. Then, if the dependent snippet is updated, the main snippet is also updated. If the dependent snippet is invalid, the main snippet becomes invalid.

If you declare variables and then initialize them, you can see them by using the `list` command, for example:

```
String firstname;  
firstname ==> null
```

```
String lastname;  
lastname ==> null
```

```
double grade;  
grade ==> 0.0
```

```
String getStudentFullName(String fn, String ln) {
    return fn + " " + ln ; }
| created method getStudentFullName(String,String)
```

```
firstname = "Wolfgang";  
firstname ==> "Wolfgang"
```

```
lastname = "Mozart";  
firstname ==> "Mozart"
```

```
System.out.println("Hello " +  
getStudentFullName(firstname,lastname));  
Hello Wolfgang Mozart
```

The output of the `list` command shows the following:

```
1 : String firstname ;
2 : String lastname ;
3 : double grade ;
4 : String getStudentFullName
(String firstname, String lastname) {
    return firstname + " " + lastname ;
}
5 : firstname = "Wolfgang" ;
6 : lastname = "Mozart" ;
7 : System.out.println("Hello" +
getStudentFullName(firstname,lastname));
```

The numbers in the output are the snippet identifiers. They are useful for manipulating a snippet (editing, dropping,

and so on). You can also list all the variables, methods, and classes that are in the code. Here's an example of listing all the variables:

```
/vars
| String firstname = "Wolfgang"
| String lastname = "Mozart"
| double grade = 0.0
```

If you decide to change the values of variables or edit a specific snippet, you run `/edit` with the snippet identifier, for example:

```
/edit 6
```

A dialog box, as shown in **Figure 2**, appears to allow you to modify the value.

If I use the editor to change lastname to my last name, I get the following result response:

```
lastname ==> "Drabo"
```

If I change the firstname to my first name, then I can rerun the print-out function by simply referring to the snippet identifier, in this case, #7:

```
/7
System.out.println("Hello" +
getStudentFullName(firstname, lastname));
Hello Constantin Drabo
```

You can use the `/save` command to save your snippets to a file, and the `/open` command allows you to open and run the file:

```
/save StudentName.jsh
```

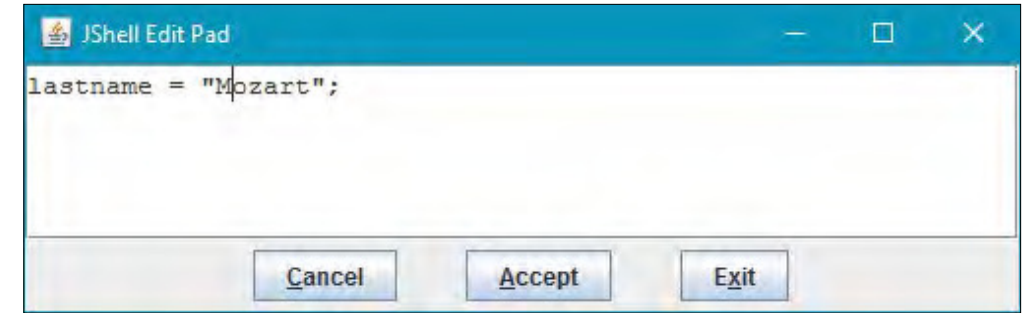


Figure 2. The built-in snippet editor

```
/open StudentName.jsh
Hello Wolfgang Mozart
Hello Constantin Drabo
```

JShell also offers some keyboard shortcuts. You can obtain the navigation history by using the up and down arrow keys. And you can use the tab key to show you the options you have for the text you've typed so far—a kind of IntelliSense feature.

Conclusion

JShell has many possible uses. The first is for beginners to try out Java code without having to write a full program. In this sense, it is a terrific learning tool. It's also a great tool for trying out small functions, validating that a web service is available and seeing what it returns, and so on. In addition, it's an excellent tool for trying out some quick layouts in JavaFX.

Whether it is used from the command line or programmatically, JShell is likely to become one of the most widely used features of JDK 9. [</article>](#)

Constantin Drabo is a software engineer living in Burkina Faso. He is a NetBeans Dream Teamer and a Fedora Ambassador for the Fedora Project. Drabo is also the founder of FasoJUG, the first Java user group in Burkina Faso (the former Upper Volta).

[This article is a substantially updated version of the JShell 9 tutorial that appeared in the July/August 2016 issue. —Ed.]



JIM LASKEY

Nashorn JavaScript Engine in JDK 9

Handy additions and support for ES6 make Nashorn even more useful.

Nashorn, the JDK's built-in JavaScript engine, has undergone a variety of improvements in this new release. Before diving into those enhancements, let me briefly set the context for these changes so that their addition makes the most sense.

Background

When I started the development of Nashorn in late 2010, I was just looking for a way to experiment with the newly minted `invokedynamic` (JSR 292) byte-code instruction. The JVM team later adopted Nashorn as a test bed for `invokedynamic`, and the Nashorn Project drove much of the performance improvements made to the `invokedynamic` implementation.

While this was going on, the Java group was discussing how JavaScript would likely grow to dominate client-side development and that integrating JavaScript with Java would be a critical element of the client/server equation. Rhino—an open source implementation of JavaScript from the Mozilla Foundation that was then the JDK offering for JavaScript—was getting long in the tooth, and further development was winding down. In November 2012, JDK Enhancement Proposal (JEP) 174, “Nashorn JavaScript Engine,” was approved, which enabled work to begin in earnest to provide a fresh, robust, secure, full-featured implementation of ECMAScript-262 Edition 5.1 (ES5) to run on the Java platform.

Initially, Nashorn found a home in a wide variety of applications, such as app servers, JavaFX applications, utilities, shell scripts, embedded systems, and so on.

Nashorn continues to have broad usage, but its use appears to have settled into three main areas:

- The development of JavaScript applications that can be run on both the client and the server. In the JavaScript world, this is known as *isomorphic development*. The advantages are huge for smaller shops that want to build front ends for both desktop and mobile services—a single programming language with a common codebase and rapid delivery. Isomorphic development also scales well for larger systems.
- Runtime adaptive or dynamic coding. The term I like to use is *soft coding*, where portions of an application can be modified after the application/server is deployed. This capability is used for everything from stored procedures in databases to application configuration management.
- Shell scripting. This consists of using JavaScript in areas where bash or Python would traditionally be used.

There is often a lot of debate about Nashorn's performance on the JVM compared to native JavaScript performance on platforms such as Google's V8. Nashorn starts out slower because it translates the JavaScript to bytecode. After that, Nashorn is at the mercy of HotSpot to deliver native code. This approach works well for long-running server applications but not as well for small and run-once scripts. The main reason we developed Nashorn in the first place was to run JavaScript and Java together seamlessly. Most Nashorn applications do a great job of orchestrating JavaScript and Java, something that V8 was not designed to do.



ES6 Support

The most important issue for JavaScript developers doing isomorphic development is the need to have client/server source code compatibility. With most browsers adopting ECMAScript 6 (ES6) as the standard level of language support for JavaScript, it was essential to bring Nashorn in line. While the Nashorn team didn't have time to deliver the complete ES6 feature set for the JDK 9 release, more ES6 features will follow in future updates. To activate ES6 support, use `--language=es6` on the command line.

New keywords. Here is what you'll find initially: the implementation of the new keywords, `let` and `const`, follow ES6 block scoping, with `const` creating an immutable local. For backward compatibility, `var` retains its ES5.1 semantics:

```
const a = 10;
a = 20; // TypeError trying to set a constant

let x = 10;
{
  let x = 20; // different scope
  print(x); // prints 20
}
print(x); // prints 10 from the outer scope
```

Support for symbols. Symbols are string-like objects introduced in ES6. They are primitives that are compared by reference instead of by value. This makes every symbol unique, which enables developers to create private object properties.

```
// a new, unique symbol
let unique = Symbol('optionalName');
myobj[unique] = 'foo';
// a shared symbol for the given name
let shared = Symbol.for('name');
myobj[shared] = 3;
```

The first example creates a distinct symbol, which can be used to create a property that is private to the current scope. The second example shows how symbols can be shared (*interned*) across an entire context. ES6 uses shared symbols to define iterators and default `toString` functions. Symbol-keyed properties are not exposed to any reflective operations.

New iterator protocol. ES6 provides a new protocol for iterating over objects:

```
// assign an iterator function to the
// Symbol.iterator property
myobj[Symbol.iterator] = function() {
    return {
        next: function() { ... }
    }
};

// Iterate over myobj using a for..of statement
for (let id of myobj) {
    print(myobj[id]);
}
```

Note the introduction of `for..of` loops. Nashorn's syntax `for each` will still be available, but the team recommends switching to `for..of` even though they are functionally equivalent.

New collections. New collection classes were added in ES6 and in Nashorn: `Map` and `Set`. These collection classes implement the new iterator protocol.

```
let map = new Map();
map.set('foo', 'bar');
map.get('foo'); // -> 'bar'
map.clear();
map.get('foo'); // -> undefined
```

The weak reference versions of Map and Set have also been

implemented; WeakMap and WeakSet. An entry in one of these collections is removed by the garbage collector when the entry value is no longer referenced by any other variable or object.

Templates. Templates are a new form of string literals using back-ticks as delimiters, which allow embedded expressions and multiline strings. Nashorn also supports ES6 “tagged” strings rendered by a function.

```
// Multiline string
'string text line 1
  string text line 2'
// Embedded expression
'string text ${expression} string text'
// Rendered by function "tag"
tag 'string text ${expression} string text'
```

Note that in `-scripting` mode, back-ticks are still used for `$EXEC` expressions.

Binary and octal numbers. Finally, there is a new syntax for binary and octal number literals.

```
// Binary number literal
0b111110111 == 503
// Octal number literal
0o767 == 503
```

In addition to these features from ES6, new capabilities enhance Nashorn's usefulness.

JavaScript Parsing API

In JDK 9, Nashorn's Parser API has been expanded to include full ES6 syntax support. The following example shows how to parse a JavaScript sample:

```
// load parser.js from Nashorn resources
//// Load the parser library
```

```
// Sample script containing an ES6 class declaration
var script = "class XYZ {}";
```

```
// Parse the script and build an abstract syntax tree
var json = parse(script);
```

```
// Convert the abstract syntax tree to JSON and print
print(JSON.stringify(json, undefined, 4));
```

The result is the following JSON output:

```
{
  "type": "Program",
  "body": [
    {
      "type": "VariableDeclaration",
      "declarations": [
        {
          "type": "VariableDeclarator",
          "id": {
            "type": "Identifier",
            "name": "XYZ"
          },
          "init": {
            // ...
          }
        }
      ]
    }
  ]
}
```

The Parsing API can also be used to analyze code or inject instrumentation, and so offers a developer lots of flexibility. NetBeans uses this API to handle most of its JavaScript functionality.

\$EXEC 2.0

One of the most popular features of Nashorn is the ability to fork processes with a simple back-tick expression. This unusual capability enables developers to create shell scripts written in JavaScript.

```
var listing = `ls -l`;
```

In this example, `listing` will contain the output string from the `ls -l` command.

The back-tick expression is just shorthand for a call to the function `$EXEC`. That is, ``ls -l`` is shorthand for `$EXEC('ls -s')`.

\$EXEC in JDK 9 is greatly improved over the previous version. You can now pass in an array of strings for the first argument, which allows you to pass arguments containing special characters, such as spaces.

```
$EXEC(["/bin/echo", "my.java", "your java"]);
```

The `$EXEC` function now has a `throwOnError` property that, if set to `true`, will raise a `RangeError` if the command fails. It is still possible to check the `$EXIT` global to check the status of the command.

```
$EXEC.throwOnError = true
`javac my.java`
<shell>:1 RangeError:
    $EXEC returned non-zero exit code: 2
```

[The last two lines appear as a single line. —*Ed.*] It is possible to better manage command I/O operations with standard redirection directives as command arguments.

```
$EXEC("echo 'my argument has spaces' > tmp.txt");
```

It is also possible to override `stdin`, `stdout`, and `stderr` by passing input and output streams as the last three `$EXEC` arguments.

Multiple commands can be issued by using semicolons or new lines.

```
$EXEC(<<EOD);
echo this ; echo that
echo whatever you want
EOD
```

Or, you can pipe the results of commands to the next command using the vertical bar symbol.

```
$EXEC("echo 'my argument has spaces' | cat");
```

Finally, you can change the values of environment variables on the fly with `pseudo cd`, `setenv`, and `unsetenv` built-in commands.

```
$EXEC("setenv PATH ~/bin:${ENV.PATH}; mycmd");
$EXEC("cd ~/bin; ls -l");
```

jjs as a REPL

The release of Nashorn with JDK 8 introduces a new command-line tool: `Java JavaScript (jjs)`. `jjs` made it easier for developers to test out Nashorn features and to launch JavaScript applications without writing Java code.

With JDK 9, `jjc` has replaced its input and output API with `jline2`, a new library for handling console input. This change means that developers can use all the standard controls that are expected when they are using a shell:

- Left and right arrows to move through the input and an option arrow to jump past symbols
- Forward and backward deletion capability

- Ctrl-k to delete the rest of a line and Ctrl-y to restore the line
- Up and down arrows to scroll through the input history
- Tab completion to expand globals, properties, and Java types
- VT100 escape sequences to format the screen

With all these small changes, life is made a little bit easier.

Performance

In JDK 9, optimistic type optimization is on by default, which means that, over time, the performance of code on Nashorn improves as stronger typing is determined by the engine.

```
function f(array, i) {  
    return array[i] + array[i + 1];  
}
```

In the example above, Nashorn will initially optimize the function `f` assuming that `i` and the contents of `array` are integers (because of the plus sign.) If it turns out that these assumptions are not correct, Nashorn will create a new edition of the function with the actual type used and hot-swap the old code with the newer version. This optimization is specialized per call site, so the best solution is always used.

Conclusion

We've seen here that the Nashorn engine in JDK 9 provides many convenient new features. This summary covers what's new in this release, but the team has a lot more in the pipeline that it hopes to show you soon. </article>

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THE LONDON JUG



The [London Java Community](#) (LJC), also known as the LJC JUG (@ljcjug), comprises developers in Europe and in the international scene. The LJC was created in 2006 when [Barry Cranford](#) from the London Java recruitment firm RecWorks sought to bring together like-minded Java

developers for sharing knowledge and skills. Since then, the LJC has grown to more than 6,000 members.

From the early days, the LJC had the good fortune to have leaders such as Zoe Slattery, Ben Evans, Martijn Verburg, Simon Maple, John Stevenson, Trisha Gee, and many other seasoned Java developers.

The LJC has been actively involved with the Java Community Process (JCP) and has won the 11th Duke's Choice Award and co-won the JCP Member of the Year honor.

With help and support from staff from RecWorks, the LJC organizes three to four events every month. One of these is a regular hack day called [HackTheTower](#), where participants gather in groups hacking on OpenJDK, doing projects in Scala or Clojure or working independently on pet projects. The LJC also runs the annual [Open Conference \(UnConf\)](#) and supports Devovxx UK and Devovxx4Kids every year. These conferences involve close cooperation between the LJC and other JUGs in the UK, such as those in Bristol and Manchester, England.

In addition, LJC members share homegrown libraries and frameworks, answer questions on the [mailing list](#), and participate in JUG-organized projects such as Adopt-a-JSR and Adopt OpenJDK. If you think that sounds fun, join up!



GASTÓN HILLAR

Working with the New HTTP/2 Client

An incubating technology in JDK 9 promises to make HTTP communication a lot simpler.

Java 9 introduces a new HTTP client API defined in Java Enhancement Proposal (JEP) 110 that implements HTTP/2 and WebSocket. This new HTTP client is included as an incubator module, and its goal is to replace the legacy `HttpURLConnection` API. In this article, I explain how to work with the asynchronous API provided by the new incubator HTTP client. Specifically, I show how to use the new HTTP client API with JShell, the new read-eval-print loop (REPL) included with JDK 9.

I start with an introduction to this new client showing basic synchronous usage. Then, I move to the asynchronous version and I use the client to perform a basic GET request; I also work with HTTP/2 over TLS. This way, you can see how to work with the new HTTP client to take advantage of the language features that provide nonblocking behavior.

A Modern HTTP Client

Whenever it was necessary to use an HTTP client in Java, it was a common practice to use third-party clients. The new incubator HTTP client is capable of working with HTTP/1.1 and HTTP/2. It is possible to work with HTTP/2 over TLS (known as *h2*) and HTTP/2 over TCP using cleartext (*h2c*).

The new client is capable of including an upgrade header field with the h2c token to request an upgrade from HTTP/1.1 to HTTP/2 over TCP. If the server doesn't support h2c, there won't be an upgrade and everything will go on working with HTTP/1.1. h2c stands for "HTTP/2 cleartext" and, therefore, it is important and easy to remember that h2c is not encrypted.

Presently, most configurations that support HTTP/2 provide support only for h2. Thus, it is very important to understand how to configure the client to work with modern versions of TLS. I include a complete example to cover this important scenario.

The combination of the new client with the upgrades in the TLS stack makes it possible to provide support for Application-Layer Protocol Negotiation (ALPN) and, therefore, the client can use this TLS extension to negotiate HTTP/2 with fewer round-trips. Based on the configuration settings you use for the HTTP client, it can negotiate the previously explained upgrade from HTTP/1.1 to h2c or select HTTP/2 (h2) from scratch. In addition, the client provides support for WebSocket conformity with RFC 6455. In this example, I focus on the HTTP features.

The new incubator module is included in `jdk.incubator.httpclient` in JDK 9. It is very important to take into account that this incubator module will be moved to another module in future JDK versions. In previous prerelease versions of the JDK, the module had a different name. You need to make sure you are running the latest JDK 9 version for the following code samples to work as expected.

I use JShell to make it easier to demonstrate the usage of this HTTP client without all the necessary specific configurations for build systems or IDEs to work with JDK 9. When I was writing this article, many IDEs and build systems were still not 100 percent compatible with JDK 9, so you might see unexpected issues. However, once the IDEs and build systems

provide full compatibility with JDK 9, you can use the code samples in a Java application built with any IDE.

The following command launches JShell with the `jdk.incubator.httpclient` module specified as a value for the `--add-modules` option. This way, JShell will resolve the `jdk.incubator.httpclient` and you will be able to use it within the JShell session. If you have multiple JDK versions installed and you don't have JDK 9 in your path, you need to run the command in the `bin` folder for JDK 9. In macOS or Linux, you might need to replace `jshell` with `./jshell`.

```
jshell --add-modules=jdk.incubator.httpclient
```

JShell doesn't require you to use semicolons (;) at the end of the statements. However, in order to make the code compatible with the Java code for building real-life applications, I prefer to use semicolons. Enter the following import statement in JShell:

```
import jdk.incubator.http.*;
```

JShell includes many import statements by default. However, if you don't work with JShell, you need to add the following additional import statements for the sample code to work:

```
import java.lang.*;
import java.net.URI;
import java.net.URISyntaxException;
```

The new module separates requests from responses. The following are the principal classes with which I work in the sample code to perform HTTP operations:

- **HttpClient**: Represents an immutable HTTP client with a specific configuration and allows you to send requests and receive responses
- **HttpRequest**: Represents an HTTP request

- **HttpResponse**: Represents an HTTP response

The API provides builders to create instances and configure the different pieces. These are static methods that start with the prefix `new`. However, the API doesn't provide builders for the headers represented with the `HTTPHeader` class. Unfortunately, the URI is still specified as a `java.net.URI` instance. Thus, if you need to use query parameters, it is necessary to format or concatenate strings.

The following lines build an `HttpClient` instance named `client` by chaining many method calls after the call to the `HttpClient.newBuilder` method that creates a new `HttpClient` builder. For example, the call to the `followRedirects` method with `HttpClient.Redirect.ALWAYS` as an argument specifies that I want the client to always follow redirects. In this case, I want to follow redirects because I want to perform an HTTP GET request to the following URI: `http://www.oracle.com`. I do not specify any desired HTTP version for the client; therefore, the client will be created as an HTTP/1.1 client that won't request an upgrade to HTTP/2 in the request header. The final chained call to the `build` method finishes the code for the builder.

```
HttpClient client = HttpClient.newBuilder()
    .followRedirects(HttpClient.Redirect.ALWAYS)
    .build();
System.out.println(client.version());
URI uri = new URI("http://www.oracle.com");
HttpRequest request = HttpRequest
    .newBuilder()
    .uri(uri)
    .GET()
    .build();
```

After the `HttpClient` instance is built, I print the result of calling the `client.version()` method. JShell displays `HTTP 1 1` because I used the default configuration. Its default

Working with Asynchronous Execution

Before demonstrating the usage of the client to work with HTTP/2 and TLS, I'll work with the asynchronous API. JShell includes many import statements by default. However, if you don't work with JShell, you need to add the following additional import statement for the next sample code to work:

```
import java.util.concurrent.CompletableFuture;
```

In the previous lines that worked with synchronous execution, I called the `client.send` method. Now, I will write similar code to build the `HttpRequest`, and this time I will call the `client.sendAsync` method that returns a `CompletableFuture<HttpResponse<String>>`. This way, you can take advantage of the support of dependent functions and actions that a `java.util.concurrent.CompletableFuture<T>` triggers upon its completion and write code that uses the `HttpResponse<String>`. [If you're not familiar with completable futures, have a look at the explanation of them in [Andrés Almiray's article on JDeferred](#) in the May/June 2017 issue of *Java Magazine*. —Ed.]

In the following code, I call `response.whenComplete()` to run code that prints the results of the `statusCode()` and `body().length()` methods that provide the HTTP status code returned by the response and the length of the body retrieved as a String, if no exception was thrown. Because the asynchronous task generated under the hood can throw an exception, I specify `HttpResponse<String> response` and `Throwable exception` when I declare the lambda expression that will be executed when the asynchronous task is completed. In the lambda expression body, I work with the `response` after making sure that the `exception` argument is null.

```
HttpClient client = HttpClient.newBuilder()
    .followRedirects(HttpClient.Redirect.ALWAYS)
```

```
.build();
URI uri = new URI("http://www.oracle.com");
HttpRequest request = HttpRequest
    .newBuilder()
    .uri(uri)
    .GET()
    .build();
CompletableFuture<HttpResponse<String>> response =
    client.sendAsync(request,
        HttpResponse.BodyHandler.asString());
response.whenComplete((HttpResponse<String> response,
    Throwable exception) -> {
    if (exception == null) {
        System.out.println(
            String.format("Status code: %d",
                response.statusCode()));
        System.out.println(String.format(
            "Body length: %d",
            response.body().length()));
    } else {
        System.out.println(String.format(
            "Something went wrong. %s",
            exception.getMessage()));
    }
});
```

With just these few lines of code in JShell, I was able to use the new HTTP client with a very basic configuration and its asynchronous API.

Working with HTTP/2 over TLS

The HTTP client uses standard Java TLS mechanisms to enable work with HTTP/2 over TLS (h2). To do this programmatically, it is necessary to create and initialize a `javax.net.ssl.SSLContext` instance and pass it as an argument to the `sslContext` method chained to the `HttpClient` builder. The

name chosen for the `sslContext` method is confusing, because it makes you think that the `HttpClient` will use the old and deprecated SSL instead of TLS to work with h2. It is important to avoid confusion about the usage of “SSL” and the various names. The `sslContext` method will configure a TLS context, not an SSL context. I will work with TLS version 1.2 (TLSv1.2) in my next example.

I also use the Bouncy Castle libraries to make it easy to load certificates. I end up generating an `SSLContext` instance configured for TLSv1.2. These Bouncy Castle libraries are very popular when developers are working with TLS in Java. Using them, I combine the new HTTP client with the usage of Bouncy Castle libraries to work with h2 in JShell. When I was in the process of writing this article, the latest version of the Bouncy Castle libraries was 1.57 and, therefore, I use the names for the JAR files that include this version number.

I won't be working with any specific build system. I will continue to make the examples work with JShell. However, you can easily use the code as a baseline to configure any build system to work with the Bouncy Castle libraries.

Download the following JAR files from the [Bouncy Castle](#) site and save them in a folder:

- bcmail-jdk15on-157.jar
- bcpkix-jdk15on-157.jar
- bcprov-jdk15on-157.jar

The following line launches JShell with the `jdk.incubator.httpclient` module specified as a value in the `--add-modules` option and the previously enumerated JAR files spec-

For software development tasks, you will find the new HTTP/2 client to be extremely useful, especially when you need to work with an interactive REPL such as JShell.

ified as values for the `--class-path` option. This way, JShell will resolve the `jdk.incubator.httpclient` and load the specified class files that allow us to work with the Bouncy Castle libraries. Make sure you launch JShell in the path in which you saved the JAR files. If you don't have `jshell` included in the path, you need to specify its full path:

```
jshell --add-modules=jdk.incubator.httpclient --class-  
path=bcpkix-jdk15on-157.jar;bcmail-jdk15on-157  
.jar;bcprov-jdk15on-157.jar
```

The following code contains all the import statements. I'm also including many import statements that JShell runs by default, to make it easy to run the code when you don't use JShell. Import statements that duplicate ones JShell brings in automatically do not generate errors.

```
import jdk.incubator.http.*;
import java.util.concurrent.CompletableFuture;
import java.lang.*;
import java.net.URI;
import java.net.URISyntaxException;
import jdk.incubator.http.*;
import java.security.KeyFactory;
import java.security.KeyStore;
import java.security.KeyStoreException;
import java.security.NoSuchAlgorithmException;
import java.security.PrivateKey;
import java.security.SecureRandom;
import java.security.Security;
import java.security.UnrecoverableKeyException;
import java.security.cert.Certificate;
import java.security.cert.CertificateException;
import java.security.cert.CertificateFactory;
import java.security.cert.X509Certificate;
import java.security.spec.InvalidKeySpecException;
```



```
import java.security.spec.PKCS8EncodedKeySpec;
import java.io.File;
import java.io.FileInputStream;
import java.io.FileReader;
import java.io.IOException;
import java.io.InputStream;
import javax.net.ssl.KeyManager;
import javax.net.ssl.KeyManagerFactory;
import javax.net.ssl.SSLContext;
import javax.net.ssl.SSLSocketFactory;
import javax.net.ssl.TrustManager;
import javax.net.ssl.TrustManagerFactory;
import
    org.bouncycastle.jce.provider.BouncyCastleProvider;
import org.bouncycastle.util.io.pem.PemObject;
import org.bouncycastle.util.io.pem.PemReader;
```

The `TLSContextHelper` class declares many static methods that will allow me to work with TLSv1.2. It is about 150 lines, so you need to download it from *Java Magazine's* [download area](#). The methods of importance in this code are

- `getKeyFactoryInstance`: Returns a `java.key.KeyFactory` instance that converts public and private keys of the RSA algorithm.
- `createX509CertificateFromFile`: Takes a certificate filename, loads the file contents, generates an instance of `X509Certificate` from the file, and returns the instance.
- `createPrivateKeyFromPemFile`: Takes a key filename in the PEM format, loads the file contents, generates an instance of `java.Security.PrivateKey`, and returns the instance.
- `createKeyManagerFactory`: Takes a certificate filename, a client key filename, and a client key password; and calls the `createX509CertificateFromFile` and `createPrivateKeyFromPemFile` methods. Subsequently, the code uses the instances returned by these methods to create

an instance of the `java.net.ssl.KeyManagerFactory` class, which it then returns.

- `createTrustManagerFactory`: Takes a certificate authority certificate filename and calls the `createX509CertificateFromFile` method. The code uses the `X509Certificate` instance, and creates and returns an instance of the `java.net.ssl.TrustManagerFactory` class.
- `createAndInitTLS12Context`: Takes a certificate authority certificate filename, a client certificate filename, and a client key filename, and creates and initializes an `SSLContext` instance with the desired TLS version (TLSv1.2). The code uses the `BouncyCastleProvider` and calls the previously explained `createKeyManagerFactory` and `createTrustManagerFactory` methods.

The `certificatesPath` variable in the following code declares a base path for the certificates that you need to run this example. You should replace the contents of this string with the path in which you have a certificate authority certificate file, a client certificate file, and a client key file. You must use files that will be compatible with the HTTP request you are going to process. I use a Windows path, `D:\JavaMagazine\http2`, as an example. However, the code that defines the variables that specify the filenames for the certificate authority certificate, the client certificate, and the client key are compatible with any platform in which you are running the code, such as Linux, Oracle Solaris, or macOS. The code calls `String.join` and uses `java.io.File.separator` to build the filenames by combining the previously explained path with filenames. Make sure you replace `ca.crt`, `server.crt`, and `server.key` with the appropriate filenames. The last line creates and initializes the `SSLContext` that I will use with the `HttpClient` to work with h2.

```
String certificatesPath = "D:\\JavaMagazine\\http2";
String caCertificateFileName =
```

```
String.join(java.io.File.separator,
            certificatesPath,
            "ca.crt");

String clientCertificateFileName =
    String.join(java.io.File.separator,
                certificatesPath,
                "server.crt");

String clientKeyFileName =
    String.join(java.io.File.separator,
                certificatesPath,
                "server.key");

SSLContext sslContext =
    SecurityHelper.createAndInitSSLContext(
        caCertificateFileName,
        clientCertificateFileName,
        clientKeyFileName);
```

The following lines build an `HttpClient` instance named `client` by chaining many method calls after the call to the `HttpClient.newBuilder` method that creates a new `HttpClient` builder. Some parts of the code are similar to the previous examples. However, in this case, notice that the call to the `sslContext` method (with the previously created `SSLContext` instance named `sslContext` as an argument) makes it possible to work with HTTP/2 over TLSv1.2. Then, the call to the version method with `HttpClient.Version.HTTP_2` as an argument forces the use of HTTP/2, specifically, HTTP/2 over TLSv1.2 because I chained the call to `SSLContext`, too.

```
HttpClient client = HttpClient.newBuilder()
    .sslContext(sslContext)
    .version(HttpClient.Version.HTTP_2)
    .followRedirects(HttpClient.Redirect.ALWAYS)
    .build();
System.out.println(client.version());
```

```
URI uri =
    new URI("https://your-rest-api-url-for-get-method");
HttpRequest request = HttpRequest
    .newBuilder()
    .uri(uri)
    .GET()
    .build();
CompletableFuture<HttpResponse<String>> response =
    client.sendAsync(request,
        HttpResponse.BodyHandler.asString());
response.whenComplete((HttpResponse<String> response,
    Throwable exception) -> {
    if (exception == null) {
        System.out.println(
            String.format("Status code: %d",
                response.statusCode()));
        System.out.println(String.format(
            "Body length: %d",
            response.body().length()));
    } else {
        System.out.println(String.format(
            "Something went wrong. %s",
            exception.getMessage()));
    }
});
```

After the `HttpClient` instance is built, the next line prints the result of calling the `client.version()` method. JShell displays HTTP_2 because I forced the usage of HTTP/2. In this case, you have to replace `https://your-rest-api-url-for-get-method` with the URI for your REST API that allows a GET method and provides a response with HTTP/2 over TLSv1.2. Remember that you are using certificates, so any wrong certificate will make the TLS handshake (reported as an SSL handshake in the old Java names for exceptions) fail. With just a few addi-

tional lines, the code performs an HTTP GET request with an asynchronous execution, as done in the previous examples. However, in this case, if the REST API is compatible with HTTP/2 over TLSv1.2, the `HttpClient` will work with this protocol instead of HTTP/1.1.

```
HttpClient client = HttpClient.newBuilder()
    .sslContext(sslContext)
    .version(HttpClient.Version.HTTP_2)
    .followRedirects(HttpClient.Redirect.ALWAYS)
    .build();

System.out.println(client.version());

URI uri = new URI("https://your-rest-api-url-for-get-method");

HttpRequest request = HttpRequest
    .newBuilder()
    .uri(uri)
    .GET()
    .build();

CompletableFuture<HttpResponse<String>> response =
    client.sendAsync(request,
        HttpResponse.BodyHandler.asString());

response.whenComplete((HttpResponse<String> response,
    Throwable exception) -> {
    if (exception == null) {
        System.out.println(
            String.format("Status code: %d",
                response.statusCode()));
        System.out.println(String.format(
            "Body length: %d",
            response.body().length()));
    } else {
        System.out.println(String.format(
            "Something went wrong. %s",
            exception.getMessage()));
    }
});
```

```
});
```

Conclusion

These simple examples demonstrated how to use the new incubator module HTTP/2 client with HTTP/2 over TLS in JShell. The module provides many additional features that you can also use from JShell and that make code easy to read. For software development tasks, you will find the new HTTP/2 client to be extremely useful, especially when you need to work with an interactive REPL such as JShell. However, the current disadvantage is that the module is included as an incubator and is subject to change. Nonetheless, if you can tolerate some API changes, the benefits of the new features justify exploring the technology. [.</article>](#)

Gastón Hillar (@gastonhillar) has been working as a software architect with Java since its first release. He has twenty years of experience designing and developing software and is the author of many books related to software development, hardware, electronics, and the Internet of Things. Hillar has been awarded the Intel Black Belt Software Developer award eight times.

learn more

[Home page for HTTP/2](#)

JEP 110: HTTP/2 Client (Incubator)

JEP 222: jshell: The Java Shell

RFC 6455 (WebSocket Protocol)

Bouncy Castle Crypto APIs

Quiz Yourself

These questions simulate the level of difficulty of two different certification tests. Those marked “intermediate” correspond to questions from the [Oracle Certified Associate exam](#), which contains material for a preliminary level of certification. Questions marked “advanced” come from the [1Z0-809 Programmer II exam](#), which is the certification test for developers who have been certified at a basic level of Java 8 programming knowledge and now are looking to demonstrate more-advanced expertise.

```
cI = (ChildIF)oI; // line n1
cC = (ChildCL)pC; // line n2
cC = (ChildCL)oC; // line n3
cI = (ChildIF)oC; // line n4
```

- Line n1 and line n3 both fail to compile.
- The casts are unnecessary in both line n1 and line n3.
- Line n3 fails to compile.
- The casts are unnecessary in both line n2 and line n4.
- Line n4 fails to compile.

```
interface ParentIF {}
interface ChildIF extends ParentIF {}
interface OtherIF {}
class ParentCL {}
class ChildCL extends ParentCL {}
class OtherCL {}
```

```
ChildIF cI = null;
ParentIF pI = null;
OtherIF oI = null;
ChildCL cC = null;
ParentCL pC = null;
OtherCL oC = null;
```

```
class P {
    private int value;
    // line n1
    public P(int v) {
        value = v;
    }
}

class S extends P {
    private int value;
    // line n2
    public S(int v, int u) {
        // line n3
        value = u;
    }
}
```

Which of these statements is true? Choose one.

- a. The code compiles without errors.
- b. Adding the following at line n2 allows the code to compile without errors: `public S(int v) {}`.
- c. Adding the following at line n3 allows the code to compile without errors: `this(v);`.
- d. Adding the following at line n3 allows the code to compile without errors: `super(v);`.
- e. Adding the following at line n1 allows the code to compile without errors: `private P(){}.`

Question 3 (advanced). You are writing a program that needs to respond to changes in a directory, such as a new version of a file being written or a file being added or deleted.

Which of these features from the standard Java SE APIs would you use in addressing this requirement? Choose one.

- `java.nio.file.Path`
- `java.nio.file.Files`
- `java.nio.file.FileVisitor`
- `java.nio.channels.AsynchronousChannel`
- `java.io.File`

Question 4 (advanced). Given the following code:

```
public static void delay() {
    try { Thread.sleep((int) (Math.random() * 10)); }
    catch (InterruptedException ie) {}
}

public static void main(String[] args) {
    int[] x = {0};
    boolean[] hold = {true};
    new Thread(() -> {
        delay();
        x[0] = 99;
        hold[0] = false;
    }).start();
}
```

```
new Thread(() -> {
    delay();
    while (hold[0])
        ;
    System.out.println("value is " + x[0]);
}).start();
}
```

And, choosing from these behaviors:

1. The program prints value is 0.
2. The program prints value is 99.
3. The JVM exits (the program stops).
4. The JVM does not exit (the program does not stop).

Which describes all the outcomes allowed by the specification?

Choose one.

- a. 2 and 3
- b. Neither 1 nor 2, and 3
- c. Either 1 or 2, and 3
- d. Either 2 and 3; or neither 1 nor 2, and 4
- e. 3 and either 1 or 2; or neither 1 nor 2, and 4



Question 1. The correct answer is option C. This question examines some aspects of assignment compatibility.

As a summary, the compiler recognizes three situations during an assignment. First, the expression on the right has an is-a relationship with the type of the expression being assigned to. The expression could be an exact instance or an instance of a class that is a subclass of the class that's


```
class AnotherImpl extends OtherCL implements ChildIF {}
```

Clearly it's possible then to have the `oC` reference point at one of these objects, and that would successfully cast to the `ChildIF` type as required. As a result, option E is incorrect.

As a side note, if the definition of `OtherCL` were `final`, guaranteeing there could be no subclasses of `OtherCL`, then line n4 would fail to compile, because no scenario like the one outlined above would be possible.

Question 2. The correct answer is option D. This question investigates the initialization of parent class elements that occurs as part of the initialization of subclasses. Java takes considerable pains to ensure that things are properly initialized. (It's not always possible to enforce that, but it's a clear goal.)

Three particular behaviors are relevant to this question. First, any time a subclass is instantiated, it must call up to a specific parent class constructor, passing the required arguments, so that the parent has a chance to be properly initialized.

Second, in the unique situation that the source code for a class does not define any explicit constructor, the compiler creates one by default. That constructor takes zero arguments, and it calls the zero-argument constructor of its parent class, the superclass, even if that class is `Object`.

Third, if a constructor does not explicitly state how to pass control to a superclass constructor, the compiler implicitly generates code in that constructor that invokes the zero-argument constructor of the parent class. This rule means that the constructor shown for `S` is equivalent to this:

```
public S(int v, int u) {
    super();
    value = u;
}
```

In this example, the child class `S`—as written—has no explicit call to any constructor in the parent class `P`, so it will invoke the zero-argument constructor of the parent. However, `P` has an explicit constructor that takes a single argument. Because of this, the child constructor cannot compile, because it implicitly calls a (nonexistent) zero-argument constructor in `P`. Therefore, option A is false.

There are two likely solutions to the problem. Either you provide the parent class `P` with a suitable zero-argument constructor to accept the child's call, or you modify the child constructor to explicitly call the constructor that does exist in the parent class. It could call the existing constructor, or you could make another constructor in `P` with different arguments, and call that explicitly from `S`. None of the options proposes that latter route, so you can ignore it.

Option B adds a single-argument constructor to the child, but that doesn't actually help. The provided constructor still has no explicit constructor call; therefore, a zero-argument constructor is still required *in the parent*. Adding such a constructor to the child does not help this situation. Note that mere matching of constructor signatures—that is, matching the argument lists—has no value here. Therefore, option B is false.

Option C is actually valid syntax, but it is incorrect for solving the problem at hand. The use of `this(v);` would try to delegate to a constructor that takes one argument, but that target constructor would have to be in the same class, not the parent. Because of this, option C is false. Also, note that constructors, unlike instance methods, are *not* inherited, so there really is no target for the call proposed here.

Option D is the correct syntax for invoking the single-argument parent class constructor. It satisfies the need for the single argument by passing the value of `v` up to the parent class constructor. From there, that value will be stored in the private member variable `value` that is a member of `P`. Because

Programmers need a mental model of how a computer works that allows reasoning about their daily work.

Question 3. The correct answer is option A. This is almost one of those troublesome “learn the API” questions, except that, in this question, you don’t have to learn method names; you just have to learn about the facilities the API can offer. That’s actually not a waste of time, because failing to learn such things often results in duplicating behavior that has already been provided for you. On that basis, I make no apology for this question.

It's also interesting to consider the private fields called `value` that exist in both `P` and `S`. Is this a really bad idea? Are they actually the same field? In fact, neither is true. Because the fields are private, there's no naming collision; each is visible only within the class that contains it. In effect, they're not visible outside their classes, so nobody can be affected by them, nor can the names collide with any other variable of that name. Also, they really do define separate fields; they're not somehow the same field. Therefore, while it might look odd when you are looking at both classes at once, this code is actually fine and you wouldn't even notice it if you didn't see both pieces of source code at once. However, if these fields were accessible outside the class—for example, if they allowed default access—the code would be pretty horrible. Such a situation is typically called *shadowing*, or sometimes variable *hiding*, and although it's manageable with careful syntax use, allowing it is just asking for maintenance trouble and can cause all kinds of misunderstandings.

The Files class is a container for static methods that perform useful operations such as copying and moving files, creating and deleting files and directories, reading and manipulating permissions, and traversing directory trees. The class also provides utility methods that can simplify access to the data in files, for example, the lines method that reads a text file as a `Stream<String>` directly. Although this is a very useful class—well worth looking at, if you haven’t already—it’s not directly suitable for solving the problem of watching for change in a directory structure, and so option B is incorrect.

The `FileVisitor` interface is used with features such as the `Files.walkFileTree` method. The visitor is used to perform operations on some or all of the files and directories in a directory tree. The interface can, therefore, examine the contents of directories, but it does so on a one-time basis, and it is not directly suited to looking for changes. Therefore, option C is incorrect.

The `AsynchronousChannel` interface is the base interface from which some interesting classes are derived indirectly. These interesting classes allow “callback” type asynchronous I/O operations, which are potentially valuable in highly concurrent systems that seek to minimize the number of threads they use. However, this capability has no direct relationship with the issue of monitoring changes in a directory. Therefore, option D is incorrect.

Finally, it's fair to point out that although the Path interface defines the register method that facilitates monitoring changes on the file system, it's not sufficient on its own. You'll also need to pass an instance of WatchService to that method. You can get an instance of WatchService from a static factory method: `FileSystem.newWatchService()`.

Question 4. The correct answer is option E. This question delves into one of the most commonly misunderstood areas of Java’s specification—the memory model—and what it means for the behavior of threaded code. Two particular points affect the behavior of the given program, and they are permitted by the specification: the visibility of written data and the perceived ordering of the write operations. Notice that one of these points is unlikely to be manifested if you run the code, but that doesn’t mean the answer I give is incorrect; it just means your system doesn’t happen to behave in this way.

Programmers need a mental model of how a computer works that allows reasoning about their daily work. Generally, the kind of model that serves well on a daily basis is a fairly

significant simplification and can get you into trouble where concurrency is concerned. Hardware engineers have some radical tricks up their sleeve to make their processors perform faster, and Java needs to allow every host it runs on to use as many of these tricks as possible to ensure good performance. Consequently, Java's specification is not written in terms of implementations but in terms of what memory effects can be relied upon. The specification uses an idea called a *happens-before relationship* to allow reasoning about which data written by one thread must be visible to another thread and when that data must be visible.

Perhaps strangely, a happens-before relationship does not actually say that one thing happens before another, at least not in the sense you would expect. It does not really relate to, nor does it actually mandate, execution order; it relates only to particular visibilities of an effect. That's perhaps surprising, but one rationale for this is that optimizing compilers have for decades indulged in the reordering of instructions. Reordering can be safe in particular situations. Let's look at a simple example:

```
double x = heavyComputation();
double y = otherComputation();
if (x > 3) doSomethingWith(x);
```

Notice that changing the order of the first two lines would make no difference to the result, but it's possible that a compiler might generate more-efficient code as a result of this reordering. It would be able to execute `otherComputation` and store the result, and then perform `heavyComputation` and immediately use the value of `x`, rather than storing `x` and having to fetch it back again for the third operation. That might seem like a small improvement, but many small improvements can add up to a large improvement.

What does a happens-before relationship tell us? If A happens before B, *and* B reads something written by A, the

happens-before relationship tells you that B will read the value written by A. Importantly, unless both the happens-before relationship and the “observation” exist, no guarantees are given. Further, just because the happens-before relationship exists in one context (for example, between two threads T1 and T2), that guarantees nothing about the visibilities of effects elsewhere where no such relationship exists (for example, a third thread T3). As you would expect, the happens-before relationship is created by the order of the code lines executed by a single thread, and happens-before relationships are transitive. Therefore, if A happens before B and B happens before C, then A happens before C. But that simple line-by-line expectation holds only for a single thread, although the transitive effect is not limited to single threads. Special steps must be taken to create any necessary relationship across threads.

In the code example in the question, nothing is done to create any happens-before relationships between the two threads that are created and started inside the `main` method. This means that the second thread—the one doing the reading—might or might not see the change from 0 to 99 in the array `x`. Similarly, it might or might not see the change from `true` to `false` in the array `hold`. It might see both changes or it might see neither, but it also might see either one without seeing the other one. (That often comes as a surprise to the developer.) Therefore, the second thread might see the 99, yet not see the change to `false`, or it might see the change to `true`, but not see the change to 99. That second possibility, which results in the program printing value is 0 and then exiting, is often a bit unexpected. (To be fair, it's also a fairly unlikely result in typical computation hardware, but the specification allows it, which means that this is a bug in the code and that's not OK.)

Therefore, let's consider the possible outcomes. What matters is what the second thread sees. If it sees the boolean value change, it prints something and the program exits.

But, if it doesn't see the boolean change, it never prints and it doesn't stop. That allows you to eliminate options A, B, and C, all of which fail to acknowledge that the program might never stop.

To evaluate the last two possibilities, you must consider the value that will be printed if the second thread sees the change in the boolean. You now know that it could correctly print either value is 0 or value is 99. Therefore, option D, which suggests that if it stops, it must have printed value is 99, but admits that it might not stop at all, is incorrect. Option E, which admits that it could either print a value and stop or print nothing and not stop, is the correct answer.

It's likely the notion that "the specification allows this" is a bit unsatisfying, so let's look at one way this might actually happen in real hardware. But first, it's important to realize that trying to reason about Java memory behavior in terms of hardware implementation is dangerous and often misleading. The *only* reliable approach is to consider the memory model and reason using that. Anyway, just to quiet that nagging "but that could never happen" feeling, here's one possible way it might happen on real hardware. First, suppose that both the threads created in the `main` method start running on their own CPUs, and those CPUs have independent caches (which is not unreasonable). Now, imagine that the writing thread runs, and it writes both 99 and `false` to its cache, not to main memory. Now, given that no happens-before relationship has been enforced between the threads, neither the underlying hardware nor the JVM has any obligation to maintain any kind of cache coherence between those threads—and whether those values end up in main memory or get moved to the other CPU's cache is undefined. Therefore, imagine that the boolean value happens to be flushed out of the cache, before the 99. (Caches usually flush a row at a time, and these two data items might happen to be in different rows. Then it would not be unreasonable that they could be flushed in the opposite order from



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